Proceedings of ISEC2006
ASME International Solar Energy Conference
July 8-13, 2006, Denver, CO

ISEC2006-99116

Overview of Solar Air Drying Systems in India and His Vision of Future Developments

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ABSTRACT :- Solar Air Drying is one of the oldest method of food preservation. For several thousand years people have been preserving grapes, herbs, Potato's, corn, milk, fruits, vegetables, spices, meat and fish by drying. Until canning was developed at the end of the 18^{th} century, drying was virtually the only method of food preservation. It is still the most widely used method. Solar Drying is an excellent way to preserve food and solar food dryers are an appropriate food preservation technology for a sustainable world. This technology makes it possible to dehydrate and preserve food professionally without compromising on quality, color, texture, enzymes, vitamins, taste and nutritional values of foods in the process. Food scientists have found that by reducing the moisture content of food to between 10 and 20%, bacteria, yeast, mold and enzymes are all prevented from spoiling it. India is blessed with an abundance of sunlight, water and biomass. Vigorous efforts during the past two decades are now bearing fruit as people in all walks of life are more aware of the benefits of renewable energy, especially solar energy in villages and in urban or semi-urban centers of India. Industries that can benefit from application of solar energy to heat air are Food, Textiles, Dairies, Pharma and Chemical. This paper reviews the present scenario of Solar Air Dryer and strategies for future developments in India.
Keywords: Solar Air Dryer, Food Preservation, India, Solar Hot Air Roof.

1. INTRODUCTION :- India is an agrarian country that has achieved good levels of agricultural production. The challenge it now faces is to find ways of improving post-harvest processing to boost the quality and shelf life of its agricultural products. Traditionally, sun drying in the open air was the main way of processing crops after harvest, and this is still practiced by small-scale producers. More recently, however, conventional fossil fuels have replaced the sun as a source of energy for the drying of crops and produce, particularly among industrial-scale producers. Both methods have drawbacks: either they are not particularly hygienic or healthy or they consume energy inefficiently and uneconomically, causing environmental pollution, which, among its other negative effects, reduces the quality of the final products. Solar thermal energy has the potential to replace fossil fuels in both industry and agriculture and represents a cleaner alternative that is more economical, more environmentally friendly and sustainable and that produces higher quality end products. With this goal in view, a group of Indian planters and energy scientists came together to improve solar air heating technology for industrial and agricultural uses. Looking at vast potential and resource availability, the Government of India, through Ministry of Non Conventional Energy Sources(MNES), provides various interventions in terms of subsidy and other fiscal benefits for the promotion of solar air heating/drying systems for agricultural applications in India.

2. RENEWABLE ENERGY SCENARIO IN INDIA

India is blessed with an abundance of sunlight, water and biomass. Vigorous efforts during the past two decades are now bearing fruit as people in all walks of life are more aware of the benefits of renewable energy, especially decentralized energy where required in villages and in urban or semi-urban centers. India has the world's largest programme for renewable energy.

India recognized the importance of increasing use of renewable energy sources for achieving a sustainable energy base in the early 1970's. During the past quarter of a century, a significant thrust has been given to the development, trial and induction of a variety of renewable energy technologies for use in different sectors. Renewable energy is seen as an effective option for ensuring access to modern energy services in our vast country. In addition, it also provides a degree of national energy security. In recent years, the rationale has been further buttressed by the environmental imperative. Local and regional environmental problems associated with the generation of conventional energy have provided a strong argument for enhancing the role of renewable energy within the broad energy development plans of the country. More recently, the Kyoto Protocol, agreed at the Conference of Parties to the Framework Convention to Climate Change, in December 1997, adds a global perspective to the environmental imperative

Background

The RETs (renewable energy technologies), such as, biogas plants and improved cookstoves have been available in India since the late 1940s, though the renewable energy programme started in earnest only after the creation of CASE (Commission on Additional Sources of Energy) in 1980, and then the DNES (Department of Non-conventional Energy Sources) in September, 1982. Programmes of DNES during 1980s were focused on the development, dissemination, and demonstration of various RETs. The programme was driven by direct Government subsidies. However, investment in RET promotion was low in comparison to those for conventional energy sources. The cumulative government expenditure for the renewable energy sector between 1980 and 1992 totalled only Rs 11.55 billion, as compared to Rs 812 billion for the power sector, Rs 335 billion for the petroleum sector, and Rs 158.5 billion for the coal sector(**GOI 1996**). In the Eighth Plan (1992-97), allocations for renewable energy were about 0.8% of the total funds allocated for the energy sector (**GOI 1996**).During the early 1990s, it was realized that faster diffusion of renewable energy sources required greater reliance on commercialization through fiscal rather than financial incentives involving the private sector - the role of the DNES had to change from that of an implementing organization to one facilitating the rapid commercial application of renewables. Partly as a result of this, the DNES was converted into a full-fledged Ministry (Ministry of Non-conventional Energy Sources, or MNES) in July 1992. Even since, the thrust of the programmes has been on market development in order to facilitate and catalyze commercialization resulting in several-fold increase in the diffusion of RETs. India is perhaps, the only country in the world with an independent ministry for the promotion of RETs.

Policy and Institutional Frameworks

Till July 14, 1993, the MNES (and earlier, the DNES) was organized on the broad basis of technology. Individual technologies were promoted through design and development support, and through the establishment of large-scale demonstration programme, e.g., the national programme for biogas development, cookstoves dissemination, and wind energy. Through by these programmes, a RET manufacturing base was created. The RET devices were procured by the government, either for demonstration projects (as for wind energy and for SPV community-lighting and power plant programmes), or for onward (subsidized) sales to consumers. As technology-support centres were created in universities to promote technological upgradation by manufacturers, and to certify the quality of devices procured by the government. The devices and the subsidies were channeled to consumers through state-level nodal agencies, which were also responsible for after-sales service and consumer support.

This policy regime was successful in the creating a fairly large and diversified manufacturing base, and an infrastructure (technology-support groups and facilities, as well as the nodal agencies) to support RET design, development, testing, and deployment. However, commercial demand for RET devices remained limited, in spite of the subsidies. This was largely because of a combination of low reliability of the devices, the lack of remunerative tariffs for RET-generated electricity, and a lack of consumer-desired features (in terms of the services and the financial commitments) in the design and sales-package.

In order to give the required focus on commercialization, market orientation, and to have greater involvement of the private sector, the MNES was restructured in 1993 on the basis of end-use applications of technologies through horizontal integration of various technologies. The restructured MNES now has sectoral groups of (a) rural energy, (b) urban/ industrial energy, and (c) power generation. Through the restructuring, emphasis shifted towards policies, planning and institutional linkages to promote RETs within each sector. Each such sector now consists of integrated programmes to serve different energy needs; for instance, cooking energy is now comprehensively dealt with, under the rural energy group rather than individual technologies being implemented separately.

The change in the structure has resulted in significant changes in the focus of the programmes. For instance, till 1992, the biogas programme had traditionally been the single largest programme within the renewable sector, accounting for over half of the funds allocated. All other individual programmes had received less than 10% of the funds. In terms of numbers, however, the dissemination of improved cookstoves has been the largest programme.Currently, the rural energy division has the largest financial allocation with the inclusion of both biogas and cookstove programmes.

The restructuring has also led to a shift from direct financial incentives (e.g., subsidies) to indirect fiscal incentives (e.g., low-interest loans, financing packages for consumers, reduced tariffs and taxes, viable power-purchase prices). This has stimulated private-sector investment in wind and Solar PV power plants, as well as encouraged RET manufacturers and financing intermediaries to address the needs of consumers in their product design. The resulting growth of the RET market has been impressive. Table 1 shows RET penetrations till 1993 (before the restructuring), and till end-1995. Significant increases have occurred in the use of RETs in wind-energy generation, Solar PV domestic lighting (particularly solar lanterns, which were earlier not even a part of the national programmes) and water pumping, and family-sized biogas plants as a result of the market-based commercialization of RET deployment.

Innovative Financing

It has often been pointed out that an important reason for the slow rate of diffusion of RETs is the high front-end cost. The creation of innovative schemes to finance investment and the emergence of **IREDA (Indian Renewable Energy Development Agency)** as an institution with substantial financial base for lending in this sector have, therefore, had a substantial impact on the commercialization of RETs.

Financing mechanism with subsidized interest rates and long repayment schedules have been in place since the inception of IREDA but it is only recently that the finances at its disposal have become significant. This has been largely due to the multilateral donor agencies preferring the use of aid to create revolving funds and greater amount of financial resources now available with the multi-lateral and bi-lateral agencies due to issues, such as, climate change becoming urgent. In the case of India, it is also said that tying World Bank aid and loan for the power sector to the much needed reforms within the sector allowing renewables to be treated as alternatives) released funds which would have otherwise gone to the conventional power development. Through the World Bank (for small hydro and windfarm development) and the GEF (Global Environment Facility) (for PV market development), IREDA would receive external aid to the tune of US $ 173 million (about Rs 5200 million) for the Eight Plan(1992-97) period. In comparison, the Government of India allocated just Rs 100 million to IREDA during the Eighth Plan.

Equally important is the shift of the emphasis of the MNES from direct financial subsidy and demonstration projects to relying more on fiscal subsidies which usually encourage serious renewable energy developers and users. The provision of soft loans has leveraged private-sector investment, and increased the funds available with IREDA. Though financial subsidies continue to be provided, there are indications that these will be phased out fairly rapidly as the fiscal incentives being strengthened. The current fiscal incentives for the renewable energy sector include 100% depreciation allowance during the first year of operation (except for hydro schemes), waiver of excise duty for most RETs and their components, and exemption from central and state sales taxes.

Lessons and Challenges

The last decade-and-a half of directed promotion of wind, biomass, and solar-energy technologies (and of other RETs) in the Indian energy-economy has provided a great deal of empirical knowledge about strategies for successful commercialization.

The first and most important lesson is that of the necessity of government involvement. The crucial roles of the government are to ensure a conducive policy environment (through the provision of remunerative prices for RET generated electricity, or of fiscal incentives), and to provide backup financial support (through direct and indirect subsidies) in order for RETs (that have yet to mature technologically and maybe financially non-viable) to move towards sustainable financial viability. Equally important is the lesson about the limits to government involvement: governments cannot develop markets; they cannot respond to consumer requirements; and they cannot indefinitely sustain the continuing introduction and maintenance of a large number of RET units.

The experience till 1993 brought out the limitations; the slow deployment of wind farms, biogas plants, and PV devices was largely due to the limited budget allocations for RETs and to consumer dissatisfaction with RET devices - they were either not reliable enough, or they did not provide the desired services, or the price, despite the subsidies, was too high. However, government involvement through the subsidies and demonstration programmes, did create a manufacturing base and a technical support infrastructure. The experience since 1993 has reaffirmed the crucial roles for which government involvement is essential. Fiscal policies have encouraged a large number of enterprises to invest in RETs, either as manufacturers (as per PV devices) or end-users (as per wind farms), and indirect subsidies have promoted the adoption of RET devices, such as solar lanterns, by end-users at acceptable terms, while simultaneously demanding a quality product that meets their requirements.

This emphasizes the third lesson: that both technology-push and consumer-pull are essential for the creation of a sustainable market. The shortcomings of the technology-push approach alone were evident in the pre-1993 period (e.g., the end-users did not find improved cookstoves meeting their needs, or the biogas plants were based on over-optimistic estimates of dung availability); the limitations of the consumer-pull approach alone is best brought out by the introduction of imported devices (such as solar home-systems) in response to consumer needs. Initially, lack of a technology support infrastructure lead to many failures and apprehensions about the technological viability of the systems. Similar experiences have occurred when new technologies (e.g., biomass gasifiers) have been promoted as solutions to the energy problems before they reached the level of maturity warranting such an effort. Aggressive promotion led to unreasonably high expectations from the RETs and the promotional effort, either explicitly or implicitly, gave the impression that these technologies could solve the energy problems of the country. Ironically, today those very efforts have resulted in the greatest barriers to the introduction of these technologies: there is a widespread feeling among those associated with the energy planning process that RETs and their possible role are grossly overrated. More than anything else, experience have emphasized that need-based targeted programmes are much more effective than broad, national programmes.

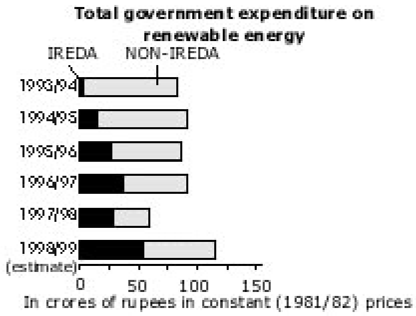
The fourth lesson illustrates the effectiveness of a portfolio of directed and targeted economic incentives: direct subsidies, indirect subsidies, and fiscal incentives. Each incentive attracts and encourages a different actor, and the appropriateness of their mix depends on the RET's level of technological development and financial viability. Consequently, it is important to continuously monitor and fine-tune the incentive structure so as to keep pace with market developments: direct subsidies become disincentives to quality improvement if a large market exists; fiscal incentives can become tax havens, thereby reducing the incentive for efficient RET utilization; and indirect subsidies can result in high transaction costs if the market becomes overstretched. However, in the final analysis, the high-leverage capability of a well-designed incentive system can provide the strategy for sustainable commercialization.

These lessons also bring out a major challenge: the need for a time-bound strategy for the economically viable commercialization of the solar-energy technologies. Currently, though both the wind and solar (PV, as well as solar-thermal) markets are buoyant, their success ultimately depends of the availability of subsidies and fiscal incentives. With constraints on public resources, such a market would soon reach a plateau. Consequently, cost-minimization strategies have to be adopted, and the incentive structure modified to promote cost reductions - this is essential if the market has to continue to grow.

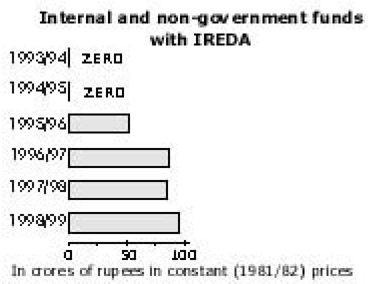
There are strong indications that this would occur, and that renewable energy sources will play an increasingly large role in the energy sector in India. The demonstration of reliability under field conditions by some technologies, changes in the institutions involved with the renewable energy sector, a shift in emphasis from direct subsidies to fiscal incentives and funds for concessional financing of investments are among the important reason for the confidence. This flexibility and maturity, both in government policy and in industry dynamics, suggest strong reasons for optimism in the growth of RETs in India.

More funds for commercializing renewable energy

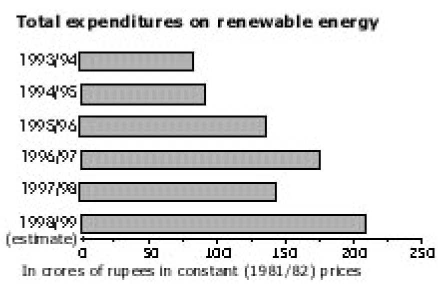
In 1992, the government overhauled the renewable energy policy. To foster commercialization, an increasing share of government funds went to the Indian Renewable Energy Development Agency (IREDA)



such international funding agencies as the World Bank, the UNDP, ADB, DGIS, ODA and the GEF welcomed the thrust on commercialization and provided more funds ...



... as a result, more funds were invested in renewable energy in India, and more effectively. The Worldwatch Institute hailed India as a 'wind energy superpower'.



Solar thermal technologies have a special relevance in India due to high availability of resource, average radiation is 4.5 - 6 kwh/m^2/day with average 280 clear days. In view of the increasing energy demand in all the sectors there is immense potential especially in domestic and industrial sector to meet thermal energy demands. Activities in this field were started in India by Department of Non-Conventional Energy Sources (DNES), which was created in 1982 to facilitate developments in the field of renewable energy, by undertaking various R&D and demonstration projects in the field of solar thermal. Realising the importance of role of renewable energy technologies, the DNES was upgraded to Ministry of Non-conventional Energy Sources (MNES) in 1992. The MNES had continued supporting solar thermal technologies with various promotional programmes.

The range of its activities cover

- promotion of renewable energy technologies,
- create an environment conducive to promote renewable energy technologies,
- create an environment conducive for their commercialization,
- renewable energy resource assessment,
- research and development,
- demonstration,
- extension,
- production of biogas units, solar thermal devices, solar dryers, solar photovoltaics, cookstoves, wind energy and small hydropower units.

The solar thermal technologies, in different stages of commercialization or R&D, are listed below.

- Solar Dryers/ Air Heating Systems with various designs.
- Solar water heating using flat plate collector.
- Solar process heating using concentrating collectors for low (40^{0}C to 80^{0}C) and medium (80^{0}C to 250^{0}C) temperature ranges.
- Solar thermal power generation
- Solar pond for process heating in low temperature range and for desalination.
- Solar cooker.
- Solar desalination
- Solar detoxification

Solar Air Dryer: Solar drying is a modification of sun drying in which the sun's rays are collected inside a specially designed unit with adequate ventilation for removal of moist air. The temperature in the unit is usually 20 to 30 degrees higher than in open sunlight, which results in a shorter drying time. While solar drying has many advantages over sun drying, lack of control over the weather is the main problem with open sun drying method.

3. USE OF SOLAR AIR DRYER FOR FOOD DRYING AND PRESERVATION

The art of drying food using solar energy is a little more complicated than you might think. We have tried to gather some practical information and to provide links to other resources. Although dried food is popular with campers, backpackers etc. this page is driven by the need for solar dryers in areas where fruit is plentiful in summer months, but because there is no simple and economic method to preserve it, much of it is left to rot, while in the winter there is hunger. Solar food drying can be used in most areas but how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. There are some basic guidelines to drying food. Most of the resources we researched recommend pre-treatment of the food, such as blanching, (boiling/steaming).Many experienced users do not pre-treat food. Wash fresh fruits and ripe vegetables thoroughly. Effective drying is accomplished with a combination of heat and air movement. Remove 80 to 90% of moisture from the food. Typical drying times range from 1 to 3 days, again depending on sun, air movement, humidity, and type of food. Once the drying process has started it should not be interrupted, do not allow to freeze. Direct sunlight is not recommended. Temperature ranges of 100 to 160 degrees will effectively kill bacteria and inactivate enzymes, although temperatures around 110 degrees are recommended for solar dryers. Too much heat especially early in the process will prevent complete drying. Food should be cut into thin slices, less than 1/2" thick and spread out on trays to allow free air movement. Rotate trays 180 degrees daily for uniform drying. Move dryer food to bottom racks. Safe tray materials include Stainless steel rack-wood slats-cheesecloth-Teflon -Teflon coated fiberglass-nylon -food grade plastics Allow food to cool completely before storing. Store food in air tight jars or plastic containers, and do not expose dried food to air, light or moisture. Most fruits taste great dried including apples, apricots bananas, grapes etc. Vegetables are best reconstituted by covering with cold water until they are near original size. They can be added in their dry form to soups/stews. Vegetables can also be ground into powders and used for instant soups or flavoring. Of all food preservation methods, that of drying foods has received the most widespread and enthusiastic publicity in recent years. Actually, drying is one of the oldest methods of food preservation. Techniques have been passed from one generation to another based on what worked and what didn't. Methods used for drying food have become sophisticated over time. Initially, salting and drying in the sun, an open room or on stove tops were the accepted methods. It wasn't until 1795 that the first dehydrator was introduced, in France, for the purpose of drying fruits and Vegetables. Today, the variety of dried foods in the marketplace has created a multimillion dollar industry. For many people, drying food at home is a convenient way to preserve foods.

Drying methods

Foods can be dehydrated by various means: the sun, a conventional oven, an electric dehydrator or a microwave oven (for herbs only). Drying, like other preservation methods, requires energy. Unless sun drying is possible, the energy cost of dehydrating foods at home is higher than for canning, and in some cases more expensive than freezing.

Solar drying is a modification of sun drying in which the sun's rays are collected inside a specially designed unit with adequate ventilation for removal of moist air. The temperature in the unit is usually 20 to 30 degrees higher than in open sunlight, which results in a shorter drying time. While solar drying has many advantages over sun drying, lack of control over the weather is the main problem with both methods. Missouri weather is not suitable for sun or solar drying because there are few consecutive days of high temperatures and low humidity. It is likely that the food will sour or mold before drying is completed.

Oven drying is the most practical way to experiment with dehydration. It requires little initial investment, protects foods from insects and dust, and does not depend on the weather. Continual use of an oven for drying is not recommended because ovens are less energy efficient than dehydrators, and energy costs tend to be high. Also, it is difficult to maintain a low drying temperature in the oven, and foods are more susceptible to scorching at the end of the drying period. Oven-dried foods usually are darker, more brittle and less flavorful than foods dried by a dehydrator.

Foods can be dried on trays in an **electric dehydrator**, a self-contained unit with a heat source and ventilation system. Electric dehydrators are used to dry foods indoors. Such dryers can be purchased or made at home and vary in sophistication and efficiency. Although the initial investment is fairly high for an electric dehydrator, it maintains low temperatures and uses less energy than an oven. The quality of the product is better than with any other method of drying. As with oven drying, there is no dependence on weather conditions.

It is **not recommended** that microwave ovens be used for drying foods, because the food will partially cook before it dries, imparting an overcooked flavor. Microwave ovens can be used to dry some herbs quickly — but watch them carefully to prevent them from catching on fire. Check the owner's manual for drying recommendations.

Drying times in conventional ovens or dehydrators vary considerably depending on the amount of food dried, its moisture content, and room temperature and humidity (and the use of fans, for oven drying). Some foods require several hours and others may take more than a day. Prolonging drying time (by using lower temperatures) or interrupting drying time may result in spoilage.

It is important to control air temperature and circulation during the drying process. If the temperature is too low or the humidity too high (resulting in poor circulation of moist air) the food will dry more slowly than it should and microbial growth can occur. Watch temperatures closely at the beginning and end of the drying period. If the temperature is too high at first a hard shell may develop on the outside, trapping moisture on the inside. This is known as **case hardening**. Temperatures that are too high at the end of the drying period may cause food to scorch. Temperatures between 120 degrees F to 140 degrees F are recommended for drying fruits and vegetables. Temperatures up to 150 degrees F may be used at the beginning, but should be lowered as food begins to dry. For at least the last hour of the drying period, the temperature should not exceed 130 degrees F.

4. EFFECTIVE TECHNOLOGIES FOR SOLAR DRYING IN INDIA :-

Solar Hot Air Roof (SHARO) is based on a simple device that is economical to install because it uses existing rooftops as solar collectors. SHAROs use two main types of system: the partial energy delivery (PED) system for tea processing and the full energy delivery (FED) system for processing spices and fish and preserving vegetables. In all of these industries, the use of SHAROs has reduced energy consumption and expenditure to such an extent that the initial costs of installing the system can be recuperated within two to three years. Nine tea factories are saving a total of US$17,500 a year in fuel costs, while the potential exists to cut fuel consumption for the processing of spices, fruit and coffee by between 70 and 90 per cent. Vegetable-drying units and tanneries are also consuming far less non-renewable energy. Overall, the use of SHAROs is cutting the fuel bills of these industries by almost US$44,000 per year and reducing environment-damaging emissions of carbon dioxide by almost 21,990 tonnes, thereby helping to arrest the deforestation that threatens the entire world, particularly developing countries. Nearly 70 per cent of the population of India is engaged in agriculture and related activities. Many of these activities involve the drying of such crops as tea, coffee, cardamom, spices and pulses, which usually involves systems that are powered by burning wood or fossil fuel. At present, the processing of pulses consumes an estimated 5 million litres of diesel fuel a year, while tea and cardamom processing need 400,000 tonnes and 50,000 tonnes of fuel wood, respectively. This puts great pressure not only on the country's forests but also on its capacity to earn foreign exchange. In addition, nearly 25 per cent of the fruit and vegetable production of India (the second largest in the world) is left to perish because it costs too much to process. Moreover, as long as fish continues to be dried and salted through traditional unhygienic open-air sun-drying techniques, the country will not be able to exploit to the full its potential 5.24 million tonnes of this low-cost protein source, which is available from its 7,500 kilometres of coastline.

India has an excellent supply of solar energy. It lies between latitudes 8° and 36° north and between longitudes 6° and 95° east and has 250 to 300 days of sunshine a year, providing 5.4 to 5.8 kilowatts per square metre of power every day. Solar heating of both air and water therefore represents an excellent alternative to the use of fossil fuels and wood.

This SHARO technology conserve energy, improve product quality and promote cleaner, healthier production by developing:

- large-scale solar hot-air generation systems that are reliable and durable, using the roofs of homes and factories as a source;
- a cost-effective solar hot-air system for agricultural and industrial processing that is environmentally friendly and efficient and that can be fitted into existing fossil fuel-driven systems;
- a low-cost methodology that does not use fossil fuel and that can be used in developing countries with suitable solar resources to process large quantities of fruits, vegetables, spices and other cash crops;
- a hygienic processing method that uses solar heating to dry and salt fish to provide a low-cost, nutritious food for poor populations; and
- a sustainable, efficient and durable substitute for fossil fuel that can be used in industrial processing through preheating or full energy delivery.

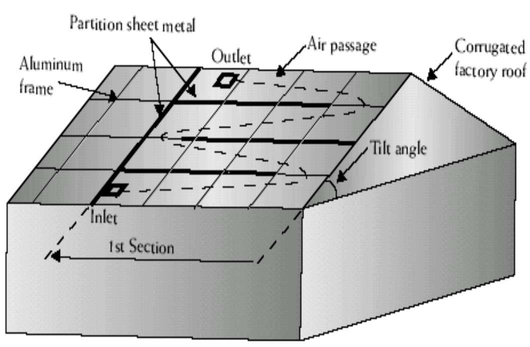


Fig.No. 1. SHARO ROOF COLLECTOR AIR FLOW DIRECTIONS

Description:- A SHARO is a blackened solar heat absorber that has a transparent cover and is well insulated on its lower side. Air is forced into the space between the cover and the absorber, where it is heated. SHARO systems are installed on existing buildings. Whereas early models converted factory roofs into absorbers, later ones constructed collectors on the south-facing roofs of factories. In these systems, the absorber is created by insulating the surface of the roof with 65-millimetre rock wool and covering this with a sheet of corrugated aluminum that has been painted matt black. Aluminum frames are used to support a four millimeter-thick tempered glass cover, whose edges are made air tight by two layers of aluminum sheet. Each 212-square metre collector is divided into four units of 53 square metres each. A centrifugal blower with a 3.75-kilowatt capacity then draws hot air from the panel into an insulated duct, from which it is distributed to the point of use. The first step in the project was to collect as much data as possible on the airflow requirements of SHARO systems and the dynamics of conventional heating systems. Special features of the SHARO include: solar collectors that are designed to allow maintenance staff to walk over them and, where dust is a problem, use of copper-coated sheets as absorbers in a system that heats air from below the absorber. In addition, a new arrangement of baffles in the collector overflow partitions is increasing the efficiency of the system by up to 50 per cent. Improvements have also been made by developing a special paint to replace the original matt black paint. As a result of this careful design and development process, SHARO systems have the following innovative features and characteristics:

- they can be fitted easily into existing conventional fossil fuel systems;
- they perform consistently and efficiently;
- they have a long life of 15 to 20 years;
- they substantially reduce fossil fuel consumption;
- they are economically viable, paying for their own installation costs within three years through reduced fuel consumption and expenditure; and
- they ensure cleaner processing, a healthier environment and more hygienic, better-quality end products.

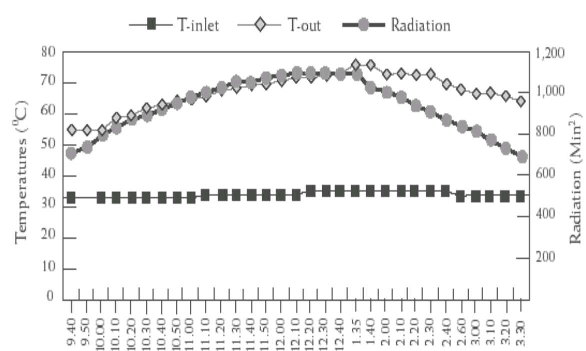


Fig.No. 2.DAILY PERFORMANCE OF A 212M^2 SHARO FOR VEGITABLE DEHYDRATION

Successful operation of SHAROs for the past six years has given agro-industries confidence in the reliability of renewable energy technologies. In many sectors, improved product quality has been noticed: tea has been found to dry better in solar-than in fossil fuel-generated hot air; pulses maintain a better colour; fish that has been dried in SHARO systems is of far better quality than that dried in the open air, which is often contaminated by dust and dirt; spice driers report a higher drying rate, improved powdering and subsequent better profits; and organic fruits that have been dried in solar hot air are now well placed in export markets. By replacing fossil fuels, solar power can reduce greenhouse gas emissions and industrial pollution, thereby promoting sustainable development. All the materials used are available locally and the technology has been developed so that it is easy to maintain, is sustainable and continues to operate at optimum performance levels for at least 10 years.

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